COLLABORATION AND OTHER FACTORS INFLUENCING INNOVATION NOVELTY IN AUSTRALIAN BUSINESSES

AN ECONOMETRIC ANALYSIS

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CONTENTS

FOREWORD

In May 2005 the Department of Industry, Tourism and Resources (DITR) and the Australian Bureau of Statistics (ABS) entered into a collaborative arrangement under statistics legislation to allow officers of DITR access to the data collected in the ABS 2003 Innovation Survey.

As a result of the above collaboration DITR and the ABS published a joint paper *"Patterns of Innovation in Australian Businesses 2003"* in January 2006.

Following on from that work, and once again through the facilitation provided by the collaborative arrangement with the ABS, this paper presents the results of an econometric investigation into innovation novelty, collaboration and related characteristics in Australian businesses.

The paper was researched and written by Donald Brunker and Umme Salma of the Industry Policy Division of DITR. Technical guidance and advice was provided by Trevor Breusch from the Australian National University.

Finally, the paper benefited from valuable comments provided by Ester Basri of DITR, and Marn-Heong Wong of the Productivity Commission.

SUMMARY AND CONCLUSIONS

In most advanced economies around the world explicit recognition is now given to the role of innovation as a key source of multifactor productivity growth, economic growth, and ultimately growth in GDP per capita. This recognition is reflected in the widespread and keen public policy focus on providing business environments that are conducive to innovation, and on actively and directly encouraging firms to be more innovative.

Many innovations, especially those of a more complex nature, seem commonly to take place in conjunction with collaboration. The range of skills and knowledge required to successfully carry out innovation often means that an innovating business may be forced to seek complementary skills to those already held in-house. Such a business may seek external skills and experience in one or more of various areas including R&D, systems modification, specialist manufacturing, or branding and marketing.

It could also be expected that collaboration might be more common and more important to 'frontier' or 'creative' innovation (products or processes that are 'new to the world') than 'adaptive' innovation (relatively minor modification of goods and services or processes already introduced elsewhere but which are 'new to Australia' or 'new to the industry' but not 'new to the world') and purely 'adoptive' innovation (adopting the manufacture/sale of goods and or services, or the introduction of processes which are 'new to the businesses' in question but which have already been introduced elsewhere).

The invention, production and marketing of products and/or processes that are new to the world is likely to require cooperative associations among a number of players, particularly for more modestly sized businesses which are unlikely to have the diversity of skill sets necessary for such innovation and which are also unlikely to have sufficient global presence to properly manage the branding and marketing of 'new to the world' products and/or processes.

The population of Australian businesses is dominated by relatively small enterprises compared with other economies such as the US and the major European economies. This characteristic together with the additional burden on product dissemination imposed by the geographical isolation of Australia suggests that collaboration might be especially important for Australian businesses' innovations that are new to the world.

This paper uses the data from the Australian Bureau of Statistics' 2003 Innovation Survey to investigate the relationship between the degree of novelty of innovation achieved by innovating Australian businesses and the extent and nature of collaborations undertaken, using an ordered categorical probit model. Other relevant business characteristics such as business size, ownership, industry, R&D intensity, and level of technology of production are also taken into account along side collaboration. Comparisons with similar investigations for Canadian manufacturers are also made.

The key findings of the paper are:

- The model predicts that a typical business in Australia that takes part in collaboration for the purpose of innovation has about a 17 per cent chance of achieving a 'new to the world' degree of novelty in its innovation, while for one that does not collaborate the chance is about 10 per cent. Thus collaboration is associated with approximately a 70 per cent increase in the chance of achieving 'new to the world' novelty or 'creative innovation'. Adaptive or first line adoptive innovation (novelty level of 'new to Australia') is also more likely for collaborating businesses, but only about 25 per cent more likely.
- Smaller businesses are less likely to achieve high degrees of novelty of innovation than larger businesses – large businesses are about 50 per cent more likely to achieve 'new to the world' innovation than small businesses, and medium sized businesses about 20 per cent more likely than small businesses.
- The manufacturing and mining sectors exhibit very similar predicted probabilities of innovation novelty, with a larger predicted chance of higher novelty than other industries. Transport and communications, finance and property, and accommodation cafes and cultural services are also quite similar to one another but with distinctly lower predicted probabilities of achieving a high degree of novelty, while trade services (wholesale and retail trade) sits somewhere between these two groupings.
- Foreign ownership is associated with a stronger likelihood of higher degrees of novelty of innovation than is pure domestic ownership – businesses with more than 10 per cent foreign ownership are about 60 per cent more likely to achieve 'new to the world' innovation than businesses that are 100 per cent domestically owned.

- An increase in collaboration diversity has quite a strong positive effect on the probability of achieving 'new to the world' innovation novelty. In contrast, a comparable increase in collaboration intensity has only between one quarter and one fifth the impact of collaboration diversity on the degree of novelty of innovation.
- Increases in R&D intensity are associated with statistically significant but relatively modest increases in the probability of higher degrees of innovation novelty. A doubling of R&D intensity from the sample average (2.2%) to 4.4% is associated with an increase in the probability of new to the world innovation from 12.1% to 12.9%
- For businesses in the manufacturing sector, those in higher technology industries are associated in general with a greater chance of higher degrees of novelty. This 'technology effect' has its strongest impact on the chance of 'new to the world' innovation where high technology manufacturers are more than twice as likely to achieve 'new to the world' innovation as low technology manufacturers. This proportionate difference dissipates rapidly with declining levels of novelty.
- The combined impact of collaboration and a high technology level on the probability of manufacturing businesses achieving higher degrees of novelty of innovation is very strong. High technology collaborating businesses have a 27 per cent chance of achieving 'new to the world' innovation. This group of businesses is nearly three and a half times as likely to achieve new to the world innovation as low technology non-collaborating manufacturers at just 8 per cent.
- The strong association between collaboration and foreign ownership and the likelihood of high levels of innovation novelty is relatively uniform across businesses of different size, and across manufacturing businesses of different technological intensity. While the estimates do find these effects to be proportionately a little stronger for smaller businesses and lower technology manufacturers, they are not significantly so.

- Analysis of innovation novelty and collaboration among Canadian manufacturers indicates that on average the probability of a Canadian manufacturing business achieving 'new to the world' innovation is about 12 per cent. Application of the same modelling technique to the Australian data yields almost the same probability for Australian manufacturers at 13 per cent. The Canadian study reports the probability of the highest degree of novelty being 'first to Canada' at just over 25 per cent, while the Australian data and modelling conducted in this paper estimates the probability of 'first to Australia' innovation to be a little over 27 per cent. On these counts the outcomes for the two countries are very similar.
- For Canadian manufacturers the probability of 'first to the world' innovation is around 10 per cent for non-collaborators and 16 per cent for collaborators – an increase of around 6 percentage points or 60 per cent. The corresponding probabilities for Australia are about 11 per cent for non-collaborators and 18 per cent for collaborators – an increase of 7 percentage points or around 65 per cent. Thus the impact of collaboration on innovation novelty among manufacturers appears very similar in Australia and Canada.
- The predicted probabilities of first to the world innovation in low and in medium technology manufacturing businesses in Australia and Canada are again quite similar. However, in Australia the change in the predicted probability of first to the world innovation between medium and high technology manufacturing businesses is almost 9 percentage points. This is very much stronger than the 0.2 percentage point predicted difference between medium and high technology intensity in Canadian manufacturing businesses.

Several conclusions can be drawn from these results: larger businesses and foreign owned businesses are more likely to achieve higher degrees of novelty of innovation than smaller businesses and domestically owned businesses. These outcomes might be expected given the costs and complexity associated with the invention, marketing and distribution of 'frontier' or 'creative' innovations, quite possibly exacerbated by the isolation of Australia from most world markets.

Businesses that engage in collaboration are significantly more likely to achieve higher degrees of innovation novelty. In this regard it appears that diversity of collaboration is much more important to achieving higher innovation novelty than intensity of collaboration. This is consistent with the view that 'frontier' innovation is both a horizontally and vertically complex activity requiring diversity and depth of knowledge and experience, and that this means that more than a single player (frequently several) is typically necessary to secure successful 'frontier' innovation.

Both collaboration and foreign ownership are strongly associated with an increased likelihood of 'new to the world' innovation, but with the intensity of these associations fairly consistent across businesses of different size and across manufacturers of varying technological intensity.

As expected, increased R&D intensity is positively associated with a higher likelihood of 'frontier' innovation, though only modestly so at typical levels of R&D intensity.

Manufacturing and mining businesses are on average more likely to achieve 'new to the world' innovation than businesses in other (non-agricultural) sectors. This may result from the fact that Australia has long been at the frontier in mining technology, and higher technology areas of manufacturing such as pharmaceuticals, and scientific instruments continue to conduct significant R&D and create new sophisticated products. Once the highest degree of novelty achieved falls from 'new to the world', even just to 'new to Australia', the difference between probabilities for mining and manufacturing businesses and businesses in the other sectors almost entirely disappears.

Finally, the results obtained in this paper for businesses in the Australian manufacturing sector are very close in most respects to those obtained in a similar study of Canadian manufacturers.

1. INTRODUCTION

In most advanced economies around the world explicit recognition is now given to the role of innovation as a key source of multifactor productivity growth, economic growth, and ultimately growth in GDP per capita. This recognition is reflected in the widespread and keen public policy focus on providing business environments that are conducive to innovation, and on actively and directly encouraging firms to be more innovative.

At the individual business level innovation is a major determinant of sustained success, and in certain highly competitive sectors may be fundamental to individual business viability itself. At the economy wide level it is vital to the international competitiveness of a country. Higher rates of innovation can provide cost based advantages through process innovations, as well as the opportunity for product differentiation, and for being first to the market with entirely new products and/or services.

Innovation as generally understood now includes much more than just the processes that lead to new goods and services arising directly from technical research and development. The application of new ideas to production processes and systems, including management are also recognised as constituting an important part of innovation. Indeed, non-technological innovation is often the source of branding differentiation and some cost based advantages, both of which can confer a competitive advantage at least in the short run.

The widespread recognition of the importance of collaboration to the innovation process and the additional value it creates is reflected in public policy initiatives designed to encourage cooperative/collaborative activity. For example, the Australian Government's Industry Cooperative Innovation Program (ICIP) seeks to encourage business to business cooperation on innovation projects that enhance productivity, growth, and international competitiveness of Australian industries, with particular focus on meeting strategic industry needs.

Many innovations, especially those of a more complex nature, seem commonly to take place in conjunction with collaboration. The range of skills and knowledge required to successfully carry out innovation often means that an innovating business may be forced to seek complementary skills to those already held in-house. Such a business may seek external skills and experience in one or more of various areas including R&D, systems modification, specialist manufacturing, or branding and marketing.

It could also be expected that collaboration might be more common and more important to 'frontier' or 'creative' innovation (products or processes that are new to the world) than adaptive innovation (relatively minor modification of goods and services, or processes already introduced elsewhere) and adoptive innovation (adopting the manufacture/sale of goods and or services, or the introduction of processes which are new to the businesses in question but which have already been introduced elsewhere).

The invention, production and marketing of products and/or processes that are new to the world is likely to require cooperative associations among a number of players, particularly for more modestly sized businesses which are unlikely to have the diversity of skill sets necessary for such innovation and which are also unlikely to have sufficient global presence to properly manage the branding and marketing of new to the world products and/or processes.

The population of Australian businesses is dominated by relatively small enterprises compared with other economies such as the US and the major European economies. This characteristic together with the additional burden on product dissemination imposed by the geographical isolation of Australia suggests that collaboration might be especially important for Australian businesses' innovations that are new to the world.

To now, there has been no quantitative empirical analysis of the strength of the association between collaboration and the nature of innovation in Australia. This paper aims to bridge that gap, at least in part, by analysing the relationship between the degree of novelty of innovation and the extent and nature of associated collaboration undertaken by Australian businesses. The relationship between innovation novelty and collaboration is analysed in the context of other key business characteristics such as business size, industry sector, foreign ownership, R&D intensity, and other innovation related activities.

2. DATA AND MODELLING

During 2004 the Australian Bureau of Statistics collected information on 6,195 businesses to establish the extent and nature of their innovation activities over the 3 calendar year period 2001, 2002 and 2003, as well as a profile of key business characteristics (such as collaboration) which have been assumed on prior grounds to be related to innovation behaviour. The aggregate results of the survey are presented in ABS (2005 (a)). The survey sought to establish whether a business had innovated during the period by asking whether it had introduced new goods and/or services, or introduced or used new processes, where the latter could be either operational processes, or organisational or managerial processes.

The survey questions relating to the collaborative (and some other) activities of businesses were asked only in relation to activities undertaken for the purpose of introducing new goods or services, or new processes. It was therefore not possible to include non-innovating businesses in the analysis of collaboration and certain other business characteristics (although in this regard see section 6 of this paper dealing with the comparison between the Australian and Canadian results).

Thus it was not possible to assess the significance of any association between collaboration and the propensity of businesses to innovate, but only between collaboration and the *degree of novelty* of innovation among innovating businesses. The next innovation survey, currently being conducted, is extending the scope of many of the business characteristics questions (such as collaboration) to include non-innovating businesses also. This will allow for a much more comprehensive analysis, including analysis of the association between the propensity of businesses to innovate and key business characteristic variables such as collaboration.

As the question relating to the degree of novelty of innovation was asked only of businesses that had introduced new goods or services, or new operational processes, businesses that had introduced only organisational or managerial innovations were excluded from the analysis.

After excluding these businesses and a small number of others with incomplete data there remained 2679 innovating businesses. Using the data on these businesses an ordered categorical probit model was estimated to analyse the association between collaboration and the degree of novelty of innovation (an outline of the theoretical underpinning of the methodology is at Appendix 1).

Several dimensions to collaboration are investigated. The most fundamental question addressed is the extent to which collaboration is associated with a higher degree of novelty of innovation.

The variable 'degree of novelty' of innovation takes the value 1, 2, 3 or 4 as the highest degree of novelty of the goods, services or processes produced by or used by an innovating business is new to the business but not new to the industry, new to the industry but not new to Australia, new to Australia but not new to the world, and finally new to the world.

The dependent variable constructed for the model is the highest degree of novelty of the firm's innovation. The independent variables in the model (the business characteristics assumed to influence the highest degree of novelty of innovation) are business size, the extent and nature of collaboration engaged in by the business, R&D intensity, the extent of foreign ownership, and the number of innovation related activities engaged in.

The modelling methodology provides estimates of the impact of the associated business characteristics on the probability of achieving any particular highest degree of novelty of innovation. The probability of the degree of innovation being *at least* as high as a particular level can be obtained by summing across the probabilities of the highest degree of novelty being (exactly) at a level greater than or equal to the particular level in question.

Variables are also constructed to reflect *diversity* of collaboration, and *intensity* of collaboration, and again the impact of these on the degree of novelty of innovation is investigated.

The question of the impact of these different aspects of collaboration on the degree of novelty of innovation is also investigated across 3 different business size categories – small (greater than or equal to 5 but less than 20 employees), medium (greater than or equal to 20 but less than 100 employees) and large (greater than or equal to 100 employees). Differences between the novelty of innovation across sectors is also briefly investigated.

Business size was included as a class variable: small, medium, and large, with the reference category being 'small'.

'Collaboration' is simply a binary variable taking the value 0 if a business reports not collaborating and 1 if it reports collaborating. 'Collaboration diversity' records the number of different *types* of collaboration engaged in by the business and ranges from 0 to 6 – the survey enquired about which of the following types of collaboration the business had engaged in over 2003: joint marketing or distribution; joint manufacturing; joint research and development; other joint venture; licensing agreement; and other forms of collaboration. It was also considered potentially of interest to investigate whether the *total number* of collaborations which a business had undertaken during the period was associated with the highest degree of novelty of innovation for the business. A collaboration intensity variable was therefore constructed by counting the number of collaborations the business had undertaken.

Six industry categories are employed in the full model: manufacturing; accommodation, cafes and restaurants and cultural services; finance and property services; mining; trade services; and transport and communications. In the industry classification employed here electricity, gas and water, and construction have been incorporated within 'manufacturing' on the basis that they are more like manufacturing businesses than straight service providers.

A variable is constructed by counting the number of different innovation related activities engaged in by the business (between 0 and 4). The 4 innovation related activities are: acquisition of machinery and equipment to develop new goods or services; training related to new goods or services; substantial new design work; and other preparations for production and delivery of new goods or services, including pre-production work (e.g. demonstration of commercial viability, tooling up and trial production runs).

Research and Development (R&D) intensity is measured as the ratio of expenditure on R&D as a percentage of total business expenditure.

Finally the extent of foreign ownership is included with no foreign ownership as the reference level, and three other levels: greater than 0 but less than 10 per cent ('Foreign (1)'), greater than or equal to 10 but less than 50 per cent ('Foreign (2)'), and greater than or equal to 50 per cent ('Foreign (3)').

A similar model is also estimated to investigate the association between technological intensity of manufacturing businesses and innovation novelty. The OECD classifies industries within the manufacturing sector into 4 technology classes. There is however not an exact concordance between the OECD industry classification and the ANZSIC classification used in the Australian Innovation Survey (AIS) 2003. The classification used here is matched as closely as is practicable to that of the OECD (see Appendix 3) with the medium-low and medium high technology groups combined into a single 'medium' technology group for the analysis in this paper.

In the model where the level of technology of manufacturing firms is analysed (section 6 of this paper), 'technology' is included as a class variable with 3 distinct classes – high, medium and low – with low technology taken as the reference level. Table 1 provides a quantitative summary of the variables used in the model.

Table 1: Value range for variables

Variable	Min value	Max value	Mean value
Innovation novelty (dependent variable)	1	4	1.81
Employment size - large	0	1	0.49
Employment size - medium	0	1	0.25
Technology level - high	0	1	0.06
Technology level - medium	0	1	0.41
Collaboration	0	1	0.33
Collaboration diversity	0	6	0.70
Collaboration intensity	0	> 100*	1.98
Number of innovation activities	0	4	1.18
R&D Intensity (%)	0	100	2.19
Foreign ownership greater than 0% and less than or equal to 10%	0	1	0.03
Foreign ownership greater than 10% and less than or equal to 50%	0	1	0.03
Foreign ownership greater than 50% and less than or equal to 100%	0	1	0.20

* Exact number withheld for confidentiality reasons

As can be seen from Table 2, the coefficients associated with the explanatory variables are for the most part highly significant. For only four of them can we not be at least 95 per cent certain that they are different from zero: medium sized businesses; the mining and the trade services industry coefficients, and the 'between zero and 10 per cent' foreign ownership coefficient. However, even with these we can be at least 93 per cent sure the coefficient on medium size and the coefficient on trade services are different from zero. Also, industry coefficients aside for the present, all coefficients have the expected signs.

The signs on the coefficients necessarily indicate the direction of the marginal effects only for the probability of novelty being 'new to the business' or novelty being 'new to the world'. A positive coefficient implies that an increase in the variable will necessarily increase the probability of being new to the world and decrease the probability of being only new to the business. For the other (intermediate) degrees of novelty the sign of a particular coefficient may or may not be the same as the sign of the marginal effect of an increase in that coefficient on the probability of a given degree of novelty (see Appendix 1 for further discussion of this phenomenon).

Table 2: Maximum likelihood estimates for explanators of highest degree of novelty (explanatory factor 'collaboration' is binary variable)

Parameter	Estimate	Standard error	Pr > Chi Sq
Intercept 3	-1.984	0.065	< 0.0001
Intercept 2	-1.233	0.059	< 0.0001
Intercept 1	-0.685	0.057	< 0.0001
Emp (M)	0.125	0.066	0.0580
Emp (L)	0.245	0.062	< 0.0001
Ind AC&R	-0.294	0.090	0.0011
Ind F&P	-0.276	0.066	<0.0001
Ind Min	-0.053	0.141	0.7072
Ind TS	-0.133	0.072	0.0651
Ind T&C	-0.264	0.086	0.0020
Active No.	0.243	0.017	< 0.0001
Collab	0.319	0.049	< 0.0001
R&D int	0.016	0.003	< 0.0001
Foreign (1)	0.116	0.128	0.3652
Foreign (2)	0.264	0.127	0.0374
Foreign (3)	0.265	0.060	< 0.0001

The monotonicity of the intercept coefficients follows from the choice of a (cumulative) ***ordered*** probit model – again, see Appendix 1. Each intercept is highly significant.

The positive coefficients on the medium and large employment size variables imply that first to the world innovation is more likely for larger businesses than small. The fact that the coefficient on the large employment variable is bigger than on the medium implies that with the size categories used the positive relationship between business size and probability of first to the world innovation is consistent across all three employment size categories.

The 'industry coefficients' are all negative. As manufacturing is the reference industry, this indicates that, all other things equal, the model predicts that manufacturing businesses are more likely to exhibit first to the world innovation than businesses in other industries.

The coefficients on foreign ownership variables imply that higher levels of foreign ownership consistently imply higher probabilities of new to the world innovation, although the difference between level 2 and level 3 foreign ownership is very small and statistically insignificant.

3. COLLABORATION AND INNOVATION NOVELTY

Table 3 shows the model estimates of the probability of an innovating business exhibiting a highest degree of novelty of precisely that specified. It compares results for small, medium, and large firms which are, or are not, collaborators (the other explanatory variables set out in Table 2 are set at their average values except for foreign ownership which is set at between 10 and 50 per cent, and the 'industry' sector which is chosen here to be manufacturing – that is each of the industry variables in Table 2 is set to zero). The three right most columns provide the proportionate changes in the probabilities of achieving the specified degree of novelty when the collaboration variable is changed from non-collaborator (0) to collaborator (1).

Table 3: Impact of collaboration on the probability of achieving a specific highest degree of novelty, by firm size – *'Average' manufacturing**

Probability of Being	Collaborator			Non-collaborator			Proportionate Increase in Probability (%)		
	L	M	S	L	M	S	L	M	S
New to World	20.2%	17.0%	14.0%	12.4%	10.1%	8.1%	62	67	73
New to Australia	26.5%	25.0%	23.1%	21.9%	19.9%	17.7%	21	25	30
New to Industry	21.2%	21.5%	21.6%	21.4%	21.0%	20.2%	-1	3	7
New to Business	32.1%	36.5%	41.3%	44.3%	49.0%	54.0%	-27	-25	-23

* Increase in probability may not match proportionate changes in probability in table because of rounding. Percentage increase in probability is correct to nearest whole number.

So, for example, the model predicts that a small non-collaborating business in the manufacturing sector (with average values for the other conditioning characteristics) has an 8.1 per cent chance of having a highest degree of novelty of 'new to the world', while a similar but collaborative business has a 14 per cent chance of 'new to the world' innovation. That is, the model suggests that collaboration is associated with a 73 per cent higher probability of such a firm having a highest degree of innovation novelty of 'new to the world', although this proportionately large increase is from a low probability base.

The proportionate increase in the probability of new to the world innovation associated with collaboration is similar though slightly smaller for medium and large businesses.

As the highest degree of novelty of innovation declines so too does the proportionate effect of collaboration on the probability of achieving the level of novelty in question. In fact with the highest degree of novelty reduced just one level to 'new to Australia' the proportionate increase in probability is reduced by more than half, and more so for larger businesses than smaller.

Table 3 yields some other interesting general results. Within the sector, larger firms have a higher chance than smaller firms of achieving higher degrees of novelty. The reverse is the case where 'new to the business' is the highest degree of novelty. The spread of probabilities across firm size is larger for collaborators than non-collaborators at 'new to the world' novelty.

Being a collaborator is associated with a higher chance of achieving higher degrees of novelty of innovation. The increase in this probability is both proportionately and absolutely larger for higher degrees of novelty but firm size differences are very small.

These general observations in relation to manufacturing also hold for the other industry sectors: business size and collaboration each have a strong positive correlation with higher degrees of novelty of innovation. The analogues of Table 3 for the other industry groupings are provided in Appendix 2.

Although the above results are qualitatively similar within the other sectors, there are quite strong differences in the model's predicted probability of achieving a given highest degree of novelty (Table 4 and Appendix 2).

The manufacturing and mining sectors exhibit very similar predicted probabilities of novelty with a larger predicted chance of higher novelty than the other industries. Transport and communications, finance and property, and accommodation, cafes and cultural services are also quite

Table 4: Predicted probability of given degree of novelty across industry *(all other characteristics at sample average)*

	Manufacturing	Mining	Trade Services	Transport & Communications	Finance & Property	Acc. Café & Cult Services
NW	12.2%	11.1%	9.7%	7.6%	7.4%	7.2%
NA	21.6%	20.8%	19.5%	17.2%	17.0%	16.7%
NI	21.4%	21.2%	20.8%	19.9%	19.8%	19.7%
NB	44.8%	46.9%	50.0%	55.3%	55.8%	56.4%

similar to one another but with distinctly lower predicted probabilities of a high degree of novelty, while trade services (i.e. wholesale and retail trade) sits somewhere between these two groups. In terms of statistical significance the group of 3 with lower probabilities of a high degree of novelty are significantly different from manufacturing at a 95 per cent level of confidence, while trade services is different from manufacturing at a 90 per cent level of confidence. Other differences are not statistically significant.

COLLABORATION AND OWNERSHIP

Table 5 shows the impact of collaboration on the probability of achieving a specified highest degree of novelty of innovation by ownership of the business. The difference in the level of foreign ownership is statistically significant only when comparing no foreign ownership with greater than 10 per cent foreign ownership. Also, Table 2 shows the coefficient on the 10 to 50 per cent foreign ownership' variable to be almost identical to that for the 'greater than 50 per cent ownership'. Table 5 compares the predicted probabilities for 'domestic' (no foreign ownership) and 'foreign' (between 10 and 50 per cent foreign ownership). Comparisons are for medium sized firms with average firm characteristics in the manufacturing sector.

As suggested by the positive coefficient on the foreign ownership variable in Table 2, foreign ownership is associated with a greater probability of higher degrees of novelty of innovation than is pure domestic ownership. Table 5 also shows the model to predict that

Table 5: Impact of collaboration on the probability of achieving a specified highest degree of novelty, by ownership – *'Average' manufacturing* medium size firm*

Probability of Being	Collaborator		Non-Collaborator		Proportionate Increase in Probability (%)	
	Foreign	Domestic	Foreign	Domestic	Foreign	Domestic
New to World	17.0%	11.2%	10.1%	6.2%	67	80
New to Australia	25.0%	20.9 %	19.9%	15.4%	25	36
New to Industry	21.5%	21.2%	21.0%	19.0%	3	12
New to Business	36.5%	46.8%	49.0%	59.4%	-25	-21

* Increase in probability may not match proportionate changes in probability in table because of rounding. Percentage increase in probability is correct to nearest whole number.

collaboration is associated with a proportionately larger increase in the probability of achieving a given degree of novelty of innovation for purely domestically owned businesses than for foreign owned businesses.

For example, the model suggests that the probability of achieving 'new to the world' innovation is 67 per cent higher for foreign owned collaborators than for foreign owned non-collaborators, but 80 per cent higher for domestically owned collaborators than for domestically owned non-collaborators.

It is also apparent from Table 5 that the positive influence of foreign ownership on the probability of achieving higher degrees of novelty of innovation is proportionately stronger for non-collaborators than for collaborators. In this regard Table 6 shows that the model predicts that the probability of a foreign owned non-collaborating 'average' manufacturing business achieving 'new to the world' innovation (10.1%) is 63 per cent higher than for a domestically owned non-collaborating similar business (6.2%). A similar comparison but for collaborating businesses shows just a 52 per cent increase in the probabilities. This phenomenon holds for each of the different degrees of novelty.

Table 6: Impact of foreign ownership on the probability of achieving a specified highest degree of novelty, by collaboration – proportionate change in probability

Probability of Being	Collaborator Proportionate change in probability (%)	Non-Collaborator Proportionate change in probability (%)
New to World	52	63
New to Australia	20	30
New to Industry	2	10
New to Business	-22	-18

4. COLLABORATION DIVERSITY/ INTENSITY AND INNOVATION NOVELTY

The preceding paragraphs report the impact of being a collaborator on the degree of novelty of innovation. The collaboration variable in that analysis is binary with value zero for non-collaborators and unity for collaborators. However, of interest also is the impact of an increase in the di*versity* and/or the *intensity* of collaboration on the highest degree of novelty of innovation – if collaboration is associated with a higher degree of novelty of innovation, as the preceding paragraphs suggest, how much further does an increase in the diversity or the intensity of that collaboration impact upon the probability of achieving a given highest degree of novelty of business innovation?

Respondents to the AIS were asked to enumerate the number of collaborations of 5 specific types and one residual 'other form of collaboration/alliance' that they had entered into over the year 2003.

Tables 7(a) and 7(b) and Figure 1 describe the frequency distributions of the constructed collaboration diversity and collaboration intensity variables. The Tables show that, consistent with the mean value for the collaboration variable of 0.33 in Table 1, almost 67 per cent of businesses in the sample reported no collaborations at all.

Table 7(a): Frequency distribution of collaboration diversity

Collaboration diversity (No. of collaboration types)	Frequency (No. of firms reporting this intensity)	Percent of respondents	Cumulative frequency	Cumulative per cent
0	1783	66.6	1783	66.6
1	337	12.6	2120	79.1
2	279	10.4	2399	89.6
3	180	6.7	2579	96.3
4	70	2.6	2649	98.9
5 to 6	30	1.1	2679	100

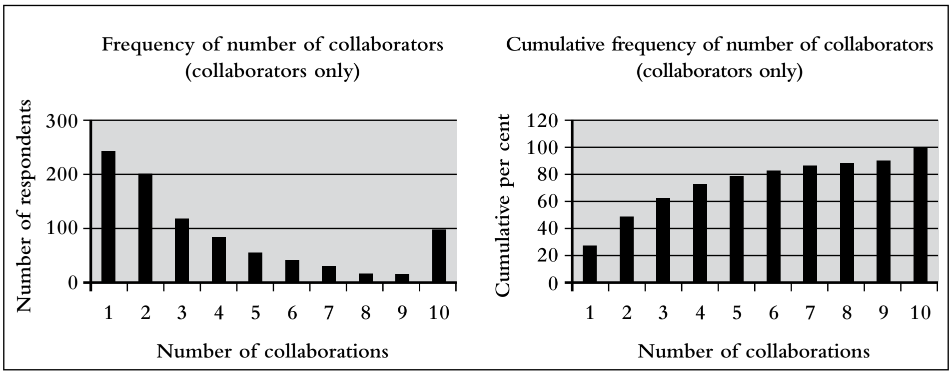
Table 7(b): Frequency distribution of collaboration intensity

Collaboration diversity (No. of collaborations)	Frequency (No. of firms reporting this intensity)	Percent of respondents	Cumulative frequency	Cumulative per cent
0	1783	66.6	1783	66.6
1	242	9.0	2025	75.6
2	203	7.6	2228	83.2
3	117	4.4	2345	87.5
4	83	3.1	2428	90.6
5	55	2.1	2483	92.7
6	39	1.5	2522	94.1
7	28	1.1	2550	95.2
8	16	0.6	2566	95.8
9	16	0.6	2582	96.4
10	18	0.7	2600	97.1
More than 10	79	2.9	2679	100

Of the 896 businesses that did report collaborating during 2003, it can be seen from the two tables that there is a relatively steep rise early in both the collaboration diversity and the collaboration intensity cumulative frequencies. Indeed, almost 70 per cent of collaborators took part in 2 or fewer *types* of collaboration (diversity – Table 7(a)), and almost 80 per cent of collaborators took part in 5 or fewer collaborations (intensity – Table 7(b)).

Among collaborators the median number of different types of collaboration is between 1 and 2 while the median number of collaborations is almost exactly 2. A few outliers reported a very large number of collaborations (the largest numbers being in excess of 100 collaborations – Table 1) making the mean number of collaborations among collaborators between 5 and 6, considerably higher than the median. The mean number of collaborations across all firms, both collaborators and non-collaborators, is 1.98 (Table 1).

Figure 1: Frequency and cumulative frequency of number of collaborations *(collaborators only – '10' equals 10 or more)*



The estimated coefficients from the regression with collaboration as a binary variable (discussed above) replaced with collaboration diversity and with collaboration intensity are provided in Tables 8 and 10 respectively. Most of the coefficients are very similar to their counterparts in Table 2. As would be expected, the coefficients on the collaboration diversity and on the collaboration intensity variables are quite different from that on the binary collaboration variable, and quite different from each other. The former variables take values from 0 to 6 and from 0 to greater than 100 respectively, while the latter variable takes only the values 0 or 1.

Table 8: Maximum likelihood estimates for explanators of highest degree of novelty (explanatory collaboration factor is 'collaboration diversity')

Parameter	Estimate	Standard error	Pr > Chi Sq
Intercept 3	-1.987	0.065	< 0.0001
Intercept 2	-1.231	0.059	< 0.0001
Intercept 1	-0.680	0.057	< 0.0001
Emp (M)	0.127	0.066	0.0537
Emp (L)	0.239	0.061	< 0.0001
Ind AC&R	-0.297	0.091	0.0010
Ind F&P	-0.269	0.066	< 0.0001
Ind Min	-0.044	0.141	0.7539
Ind TS	-0.125	0.072	0.0827
Ind T&C	-0.259	0.086	0.0025
Active No.	0.237	0.017	< 0.0001
Collab diversity	0.155	0.019	< 0.0001
R&D int	0.016	0.003	< 0.0001
Foreign (1)	0.099	0.128	0.4399
Foreign (2)	0.281	0.127	0.0264
Foreign (3)	0.273	0.060	< 0.0001

Table 9 presents the predicted impact on innovation novelty resulting from changing the collaboration diversity variable from 1 to 2. This increase captures an additional 279 businesses (about 10.4 per cent of all innovating businesses) in the cumulative distribution. Recall from Table 1 that the average value of the diversity variable is 0.7. So we have chosen the nearest positive integer value to the mean as the base value and applied a shock which will capture a little over 10 per cent of all innovating businesses. We will shock the collaboration intensity variable in a similar manner so that there is some basis for comparing the impact of changes to the diversity variable with changes to the intensity variable.

The 'degree of novelty' probabilities when collaboration diversity equals 2 are very close to the corresponding probabilities in Table 3 for collaborators. This reflects the fact that *among collaborators* a diversity value of around 2 is somewhat 'typical'(see cumulative frequency chart in Figure 1).

Table 9: Impact of collaboration diversity on the probability of achieving a specified highest degree of novelty, by firm size – *'Average', manufacturing**

Probability of Being	Collab Div = 2			Collab Div = 1			Proportionate Increase in Probability (%)		
	L	M	S	L	M	S	L	M	S
New to World	19.9%	17.0%	13.9%	15.9%	13.3%	10.8%	25	27	29
New to Australia	26.6%	25.1%	23.2%	24.5%	22.8%	20.7%	8	10	12
New to Industry	21.4%	21.7%	21.7%	21.7%	21.7%	21.3%	-2	0	2
New to Business	32.1%	36.2%	41.1%	37.9%	42.2%	47.2%	-15	-14	-13

* Increase in probability may not match proportionate changes in probability in table because of rounding. Percentage increase in probability is correct to nearest whole number.

The increase in collaboration diversity from 1 to 2 has quite a strong positive proportionate effect on the probability of reaching 'new to the world' innovation novelty, and that proportionate impact is slightly higher for smaller businesses (29 per cent) than medium (27 per cent) and large (25 per cent). The absolute difference in probability resulting from increased collaboration diversity is also larger for 'new to the world' novelty than lower degrees of novelty, but is slightly lower for smaller firms (3.1 percentage points) than medium (3.7 percentage points) and large (4 percentage points).

In assessing the impact of an increase in collaboration intensity on the predicted probability of achieving a specified degree of novelty of innovation the collaboration intensity variable has been set at 2 for the base case and at 6 for the shocked case. These values are chosen to be consistent with the approach taken in the case of collaboration diversity. The mean value of the intensity variable is 1.98. In addition, there are 294 businesses reporting greater than 2 but no more than 6 collaborations, and this amounts to just under 11 per cent of all innovating businesses – recall that the shock to innovation diversity captured 10.4 per cent of all innovating businesses.

However, the shock to intensity has both absolutely and proportionately very little impact on the probability of achieving any chosen level of novelty (Table 11), although the coefficient is significant at better than a 99 per cent confidence level.

Table 10: Maximum likelihood estimates for explanators of highest degree of novelty (explanatory collaboration factor is 'collaboration intensity')

Parameter	Estimate	Standard error	Pr > Chi Sq
Intercept 3	-1.927	0.064	< 0.0001
Intercept 2	-1.179	0.058	< 0.0001
Intercept 1	-0.636	0.056	< 0.0001
Emp (M)	0.136	0.066	0.0397
Emp (L)	0.267	0.061	< 0.0001
Ind AC&R	-0.279	0.090	0.0020
Ind F&P	-0.257	0.066	< 0.0001
Ind Min	-0.043	0.141	0.7609
Ind TS	-0.121	0.072	0.0927
Ind T&C	-0.263	0.085	0.0020
Active No.	0.258	0.017	< 0.0001
Collab intensity	0.008	0.002	0.0002
R&D int	0.017	0.003	< 0.0001
Foreign (1)	0.130	0.127	0.3067
Foreign (2)	0.303	0.126	0.0168
Foreign (3)	0.280	0.060	< 0.0001

These results suggest that increasing the diversity of collaboration is associated with much larger increases in the probability of higher degrees of novelty than 'comparable' increases in the intensity of collaboration. This is consistent with the view that 'new to the world' innovations are generally very complex processes that require diverse input from a number of different players as well as a variety of types of association.

Table 11: Impact of collaboration intensity on the probability of achieving a specific highest degree of novelty, by firm size – *'Average manufacturing'**

Probability of Being	Collab inten 6			Collab inten 2			Proportionate Increase in Probability (%)		
	L	M	S	L	M	S	L	M	S
New to World	16.7%	13.6%	10.9%	15.8%	12.9%	10.3%	5	6	6
New to Australia	24.7%	22.7%	20.5%	24.2%	22.2%	19.9%	2	2	3
New to Industry	21.4%	21.4%	20.9%	21.4%	21.3%	20.8%	0	0	1
New to Business	37.3%	42.3%	47.7%	38.6%	43.7%	49.0%	-3	-3	-3

* Increase in probability may not match proportionate changes in probability in table because of rounding. Percentage increase in probability is correct to nearest whole number.

5. R&D INTENSITY AND INNOVATION NOVELTY

As indicated in Table 1, the R&D intensity variable has a range from 0 to 100 (per cent) and has a mean value across the sample of 2.19. The estimated coefficient on R&D intensity is 0.016 (Table 2) and is statistically significant.

The impact of a change in R&D intensity on the probability of achieving specified highest degrees of novelty of innovation in manufacturing is provided in Table 12. The impact is calculated at the mean and the shock being modelled is an increase in R&D intensity from its mean of 2.19 to 4.38 – ie. a doubling. This means that the corresponding proportionate changes in probabilities are the elasticities of these probabilities with respect to R&D intensity, at the mean.

Table 12: Impact of R&D intensity on the probability of achieving a specific highest degree of novelty, by firm size – *'Average manufacturing'**

Probability of Being	R&D intensity = 4.38%			R&D intensity = 2.19%			Proportionate Increase in Probability (%)		
	L	M	S	L	M	S	L	M	S
New to World	15.6%	12.9%	10.4%	14.7%	12.1%	9.8%	6.1	6.6	6.1
New to Australia	24.1%	22.3 %	20.2%	23.6%	21.7%	19.6%	2.1	2.8	3.1
New to Industry	21.6%	21.4%	21.0%	21.6%	21.4%	20.8%	0	0	1.0
New to Business	38.7%	43.4%	48.4%	40.1%	44.8%	49.8%	-3.5	-3.1	-2.8

* Increase in probability may not match proportionate changes in probability in table because of rounding. Percentage increase in probability is correct to nearest whole number.

The R&D intensity elasticity of the probability of the 'average' manufacturing business achieving new to the world innovation is around 6 per cent. For new to Australia innovation it is around 3 per cent.

6. INNOVATION NOVELTY, COLLABORATION AND TECHNOLOGY INTENSITY IN MANUFACTURING BUSINESSES

Among the 3 main non-agricultural market sectors of the Australian economy - mining, manufacturing, and services – manufacturing exhibits the highest proportion of innovating businesses, and generally a greater probability of achieving a higher degree of novelty of innovation. This outcome is consistent with a number of other indicators of innovation related activity. For example, manufacturing accounts for the highest share of business expenditure on R&D among the 3 sectors (46% in 2003-04), while in terms of expenditure on all aspects of innovation it accounts for over 27 per cent of such business expenditure (ABS 2005(a) and (b)).

It might be expected that the relatively intense involvement of manufacturing in innovation related activity is positively correlated within the sector with higher technology industries. Indeed, the level of technology of individual businesses was a key explanatory variable in the study of innovation novelty in Canadian manufacturing businesses conducted by Therrien and Chang (2003). The concordance between industries within manufacturing and the three levels of technology: high, medium and low is provided at Appendix 3.

A model along similar lines to those discussed above is estimated for innovating manufacturing businesses, with a technology variable also included. In this model however, only businesses classified as manufacturing under the ANZSIC system are included - recall that in the model covering all innovating businesses electricity, gas and water and construction were included in manufacturing for the purpose of establishing industry class variables.

It should be noted that this ordered categorical probit model is quite different from the methodology employed by Therrien and Chang for the Canadian manufacturing data set. For the purposes of comparison a similar approach to theirs is applied to the Australian data in section 7, but the present simpler approach presented here is preferred for the reasons discussed in the concluding remarks to section 7.

The maximum likelihood estimates for the model for innovating manufacturing businesses, including technology variables, are presented in Table 13.

Table 13: Maximum likelihood estimates for explanators of highest degree of novelty including technology level (manufacturing businesses only)

Parameter	Estimate	Standard error	Pr > Chi Sq
Intercept 3	-2.084	0.090	< 0.0001
Intercept 2	-1.273	0.080	< 0.0001
Intercept 1	-0.784	0.077	< 0.0001
Emp (M)	0.106	0.090	0.2368
Emp (L)	0.381	0.090	< 0.0001
Mfgtech (M)	0.188	0.071	0.0080
Mfgtech (H)	0.527	0.146	0.0003
Active No.	0.281	0.024	< 0.0001
Collab	0.238	0.073	0.0001
R&D int	0.014	0.004	0.0008
Foreign (1)	0.208	0.225	0.3571
Foreign (2)	0.222	0.200	0.2672
Foreign (3)	0.071	0.093	0.4427

It is of interest to compare the coefficients (and their standard errors) in Table 13 with those in Table 2. As we are focussing on manufacturing the explicit industry variables in Table 2 are all set to zero so that when comparing the estimates we can ignore those coefficients. However, Table 13 has the additional technology variables.

There are a couple of immediate observations. First, the medium employment size variable is now most definitely not significant – in Table 2 it was significant at the 6 per cent level. The large employment variable remains highly significant. Second, in Table 2 the variable for 'greater than 50 per cent foreign ownership' was equal to 0.265 and was highly significant – it is now equal to 0.071 and is most definitely not significant. This suggests a high degree of collinearity between the medium or high technology variable and the high foreign ownership variable. The presence of collinearity decreases the efficiency of the estimates but does not introduce bias.

Using the estimates from Table 13 we compute the predicted probabilities of an 'average' manufacturing business achieving a given highest degree of novelty of innovation for each of the three technology levels.

Table 14: Probability of having specified highest degree of novely – *(average manufacturing business)*

Probability of Being	High Tech	Med Tech	Low Tech
New To World	21.4%	12.9%	9.3%
New To Australia	29.3%	24.5%	21.2%
New To Industry	18.7%	19.3%	18.7%
New To Business	30.6%	43.3%	50.8%

Table 14 confirms our expectation that manufacturing businesses in higher technology groups are associated in general with larger probabilities of higher degrees of novelty of innovation. The 'technology effect' is strongest for new to the world innovation where high technology manufacturers are generally more than twice as likely to achieve new to the world innovation as low technology manufacturers. This differential dissipates rapidly as the degree of novelty of innovation declines.

It is worth noting in passing that the probabilities in the centre column of Table 14 are quite similar to those in the left most column of Table 4 which are based on the first model run on all innovating businesses but with separate industry variables. The inclusion of electricity, gas and water, and construction within 'manufacturing' in the first model estimation but exclusion here appears to have had little effect on the probabilities of 'new to the world' and 'new to the business' innovation novelty compared to Table 4, while shifting the probability more towards 'new to Australia' novelty and away from 'new to the industry' novelty compared with Table 4.

The combined impact of collaboration and technology level on the probability of businesses achieving a given highest degree of novelty of innovation is set out in Table 15. High technology collaborating businesses have a 27.4 per cent chance of achieving new to the world innovations. This group of businesses is nearly three and a half times as likely to achieve new to the world innovation as low technology non-collaborating manufacturers at just 8 per cent.

Table 15: Impact of collaboration on probability of highest level of innovation novelty, by technology intensity ('average' manufacturing business)

Probability of Being	Collaborator			Non-Collaborator			Proportionate Increase in Probability (%)		
	HT	MT	LT	HT	MT	LT	HT	MT	LT
New to World	27.4%	17.4%	13.0%	18.9%	11.1%	8.0%	50	57	63
New to Australia	30.9%	27.5%	24.6%	28.3%	23.0%	19.5%	9	20	26
New to Industry	17.4%	19.2%	19.3%	19.0%	19.1%	18.2%	-9	-1	6
New to Business	24.2%	35.9%	43.1%	33.8%	46.8%	54.3%	-28	-23	-21

The impact of collaboration on the probability of higher degrees of novelty is proportionately stronger for low technology businesses, but in the case of new to the world innovation is absolutely larger for high technology businesses.

Some further reference to these results will be made in the following section.

7. COMPARISON WITH CANADIAN ESTIMATES FOR MANUFACTURING BUSINESSES

The Canadian Survey of Innovation 1999 collected innovation related data on manufacturing and selected natural resource industries. A variety of studies analysing the data from that survey is presented in Gault 2003.

The study therein by Therrien and Chang provides an analysis of the impact of collaboration on innovation novelty among Canadian manufacturing businesses. Given that research, it is of interest to compare findings based on the Australian data with those reported in the Canadian work.

In order to make the comparison as valid as possible the same econometric technique as that used in the Canadian study is employed in respect of the Australian data for manufacturing businesses; namely a 2 stage Heckman procedure using a binary probit on innovation followed by an ordered probit on the degree of novelty of that innovation (see Therrien and Chang (2003), and Wooldridge (2002) pages 560 - 564). This technique is used to correct for bias arising from certain unobserved data. The correction is effected by introducing a new variable, the inverse Mills ratio, into the second equation – this variable appears last in Tables 16 and 17.

Also, as far as possible the same observed variables as used by Therrien and Chang are employed here. Table 16 sets out the estimated coefficients for the ordered probit model on innovation novelty based on the Australian data and on the model results reported by Therrien and Chang. It should be noted that the Canadian analysis covers only manufacturing businesses with at least 20 employees. The size categories used are small (20 to 49 employees), medium (50 to 249 employees) and large (more than 250 employees). These are different from the size categories used earlier in this paper, but are adopted here for consistency with the Canadian work.

The Canadian study reported that the probability of being a world first innovator was about 12 per cent when all variables were set at their average value. The model also predicted that for such an 'average' Canadian business, being involved in collaboration increased the probability of being a world first innovator by "more than 5.8 percentage points".

Two conditioning variables with statistically significant coefficients in the Canadian model were not significant in the Australian model. The Prairies region was the only region in the Canadian model with a significant effect relative to the reference region (Atlantic). In the Australian model none of the states and territories had a significant effect relative to the reference state of South Australia. Also in the Australian model medium employment size was not significantly different from small employment size whereas these were significantly different in the Canadian model.

Table 16: Estimated coefficients for ordered probit of innovation novelty in manufacturing – Australia and Canada

	AUSTRALIA		CANADA	
	Coefficient	Standard error	Coefficient	Standard error
Intercept 1	-1.772*	0.18	-1.879*	0.13
Intercept 2	-0.894*	0.17	na#	na
Intercept 3	-0.389*	0.17	na	na
Emp (M)	0.084	0.10	0.128*	0.04
Emp (L)	0.218*	0.11	0.258*	0.06
Tech (M)	0.267*	0.08	0.288*	0.04
Tech (H)	0.615*	0.19	0.299*	0.10
Collab	0.311*	0.08	0.279*	0.04
Activ No.	0.205*	0.03	0.115*	0.02
Gov Prog	0.104	0.17	0.136*	0.04
Vic/Quebec	0.056	0.14	-0.037	0.09
NSW/Ont	0.226	0.14	0.120	0.09
Qld/Prairies	0.112	0.16	0.226*	0.1
WA/Br.Col	-0.029	0.18	0.067	0.1
Tas/ na	-0.081	0.21	na	na
ACT/ na	-0.021	0.39	na	na
NT/ na	-0.289	0.67	na	na
Mills	-0.475*	0.14	-1.055*	0.11

* Significant at the 5 per cent level; na 'not applicable'.

Unclear why no second intercept is provided for Canadian model

To compare the Canadian results with those for Australia using the same estimation technique applied to the Australian Innovation Survey data, it was necessary to establish average values for all the variables. This was straight forward for the Australian data and is provided for the Canadian data in Therrien and Chang, with the exception of the average value of the inverse Mills ratio for Canada. This had to be imputed from the data and modelling results provided.

The imputation was possible from knowing that for the average Canadian business the probability of being first to the world was around 12 per cent. The imputed value was determined by setting all other variables at their average values (provided in the Canadian paper) and searching for the value of the inverse Mill's ratio which yielded the required magnitude of (around) 12 per cent for the probability of new to the world innovation. This technique yielded an imputed average value for the inverse Mill's ratio of 0.42 for Canada, and compares with an average value of the inverse Mill's ratio for Australia of 0.5

Table 17 provides the values of the variables in the (second stage) ordered probit on innovation novelty used for establishing the base case for the comparative analysis of first to the world innovation.

Table 17: Estimated coefficients and base case variable values for ordered probit of innovation novelty in manufacturing – Australia and Canada (new to the world)

	AUSTRALIA		CANADA	
	Coefficient	Base case value of variable	Coefficient	Base case value of variable
Intercept 1	-1.772*	1	-1.879*	1
Intercept 2	-0.894*	0	na#	na
Intercept 3	-0.389*	0	na	na
Emp (M)	0.084	1	0.128*	1
Emp (L)	0.218*	0	0.258*	0
Tech (M)	0.267*	1	0.288*	1
Tech (H)	0.615*	0	0.299*	0
Collab	0.311*	0.35	0.279*	0.36
Activ No.	0.205*	1.52	0.115*	3.95
Gov Prog	0.104	0.06	0.136*	0.60
Vic/Quebec	0.056	0.36	-0.037	0.37
NSW/Ont	0.226	0.31	0.120	0.41
Qld/Prairies	0.112	0.15	0.226*	0.12
WA/Br.Col	-0.029	0.10	0.067	0.10
Tas/ na	-0.081	~	na	na
ACT/ na	-0.021	~	na	na
NT/ na	-0.289	~	na	na
Mills	-0.475*	0.50	-1.055*	0.42

* Significant at the 5 per cent level; na 'not applicable'.

Unclear why no second intercept is provided for Canadian model

~ Proportions withheld for confidentiality

The intercept relevant to 'first to the world' is switched on (given the value 1) as is medium employment size, and medium technology intensity. The collaboration, number of innovation related activities, and government program variables are set to their average values for each country. The reference state in Australia is South Australia and the reference region for Canada is the Atlantic region. Each non-reference state or territory in Australia and province in Canada was given a weight according to its share of businesses in the total of all non-reference region businesses.

At the values set out in Table 17 the probability of being first to the world in Canada was 12.1 per cent, and in Australia a very similar 12.8 per cent. Therrien and Chang also report that the probability of a highest degree of novelty being 'first to Canada' was 25.5 per cent. The corresponding estimated probability of first to Australia innovation in manufacturing is 27.0 per cent. In this regard the models yield very similar results.

To compare the impact of collaboration on the probability of being first to the world across the two models, the collaboration variable was first set to zero and the predicted probabilities of first to the world innovations were computed for Australia and Canada. The collaboration variable was then set to unity and the probabilities recomputed. The difference between the probabilities under zero collaboration and unitary collaboration was then computed for the two countries.

For Canada the probability of first to the world innovation was 10.2 per cent in the absence of collaboration and 16.1 per cent with collaboration – an absolute change of 5.9 percentage points. For Australia the corresponding outcomes were 10.7 per cent without collaboration and 17.5 per cent with collaboration – an absolute difference of 6.8 percentage points.

Thus, while the impact of collaboration on the probability of first to the world innovation is predicted to be a little higher for the average manufacturing business in Australia than for the average manufacturing business in Canada, the similarities are remarkably strong both in terms of levels and of the impact of a change from non-collaboration to collaboration.

One of the more obvious differences in the Canadian and Australian coefficient estimates set out in Table 17 relates to the technology intensity variables. The estimated coefficients on medium technology intensity are quite similar for Australia and Canada. However, the estimated coefficient on high technology for Australia is more than double that for medium technology, whereas for Canada it is little changed.

The relatively unchanged coefficient on the high technology variable compared with the medium technology variable reported in the

Canadian study is surprising, even in its own right. The paper reports that the proportion of all innovating businesses that have made first to the world innovations among low technology, medium technology, and high technology businesses was 9 per cent, 18 per cent, and 27 per cent respectively, yet the reported coefficient on high technology in the Canadian model is essentially no different from that for medium technology. The corresponding proportions in the Australian survey were very similar at 9 per cent, 17 per cent, and 26 per cent respectively, but the coefficient on the high technology variable in the Australian model is more than twice that on the medium technology variable.

We expect this difference in the models to yield quite different outcomes for the predicted Canadian and Australian world first probabilities for high technology and medium technology manufacturing businesses, and this is indeed the case.

The predicted probabilities of first to the world innovation in low and in medium technology manufacturing businesses in Australia and Canada are quite similar. The change in the predicted probability between low technology and medium technology businesses in the two countries is 4.8 percentage points in Australia and 4.9 percentage points in Canada.

Table 18: Probability of first to the world innovation in Australian and Canadian manufacturing, by technology intensity.

	High Tech	Med Tech	Low Tech
Australia	21.5%	12.8%	8.0%
Canada	12.3%	12.1%	7.2%

However, in Australia the change in the predicted probability of first to the world innovation between medium and high technology manufacturing businesses is 8.7 percentage points. This is considerably higher than the 4.8 percentage point difference between low and medium technology intensity, and very much stronger than the 0.2 percentage point predicted difference between medium and high technology intensity in Canadian manufacturing businesses.

The predicted probabilities of new to the world innovation in the Australian model exhibit a profile much closer to the profile of the ratios in the survey data than do the probabilities suggested by the Canadian model. It is of note that our (preferred) model specification discussed in section 6 of this paper exhibits a probability profile of new to the world innovation across technology level in Australian manufacturing (see Table 14) almost exactly the same as that above where the data and modelling technique was constrained to match as closely as possible the 2 stage Heckman approach used by Therrien and Chang.

The number of innovation related activities undertaken by a business is a common variable in both the Australian and Canadian models but with quite different estimated coefficients. The impact on first to the world probabilities from a unit change in the number of innovation related activities was computed for each country at the country mean value. For Australia the mean value for innovation activity number was 1.52 and for Canada 3.95. A one unit change in these variables changed 'first to the world probability' for Australia from 12.8 per cent to 17.6 per cent – a 4.8 percentage point increase. For Canada the outcome was to increase first to the world probability from 12.1 per cent to 14.6 per cent – a 2.5 percentage point increase.

The magnitude of the predicted impact in Australia is almost double that in Canada. However, the mean value, at which the shock is imposed, is much higher for Canada than for Australia. In recognition of this a second equal *proportionate* (10 per cent) impact in the number of innovation activities rather than equal absolute change was applied. For Australia the number of innovation activities was raised from 1.52 to 1.67 and for Canada from 3.95 to 4.34. The resulting increase in first to the world probability was 0.7 percentage points (or a 5.5 per cent increase) for Australia and 0.9 percentage points (or a 7.4 per cent increase) for Canada.

Thus, the elasticity (at the mean) of first to the world probability with respect to innovation activities is 55 per cent in Australia and 74 per cent in Canada.

8. CONCLUDING REMARKS

This paper has employed the data collected in AIS 2003 to investigate the strength of association of collaboration and the nature of that collaboration with the degree of 'creativity' of innovation as measured by the highest level of novelty of innovation achieved by Australian businesses. The strength of association between innovation novelty and business size, the extent of foreign ownership, industry sector, R&D intensity, and level of technology in manufacturing is also investigated. Comparisons are also made with the results of the Therrien and Chang study of innovation novelty for Canadian manufacturing businesses.

The analysis is based on the estimation of ordered categorical probit models. The impact on the probability of a given level of innovation novelty resulting from a shock to a conditioning variable of interest is estimated, and compared across other business characteristics.

This study finds a strong positive association between collaboration and the highest level of innovation novelty achieved by Australian businesses. Collaboration diversity is also strongly associated with innovation novelty, but collaboration intensity is not.

Business size and higher degrees of foreign ownership are also positively associated with innovation novelty, and businesses in the manufacturing and mining sectors have a significantly higher probability of achieving higher levels of innovation novelty than do businesses in the other sectors covered.

As expected, increased R&D intensity is positively associated with a higher likelihood of 'frontier' innovation, though only modestly so at typical levels of R&D intensity.

Comparisons of the impacts of collaboration and of the level of technology on innovation novelty in the Australian manufacturing sector are made with the Therrien and Chang results for Canadian manufacturers. The analysis reveals in general very similar outcomes for the two countries. The only exception of some note is that the Canadian study finds very little difference in the likelihood of 'new to the world' innovation between medium technology and high technology Canadian manufacturers, whereas the Australian estimates made here indicate that high technology manufacturers have markedly higher propensity to make 'new to the world' innovations than do lower technology manufacturers.

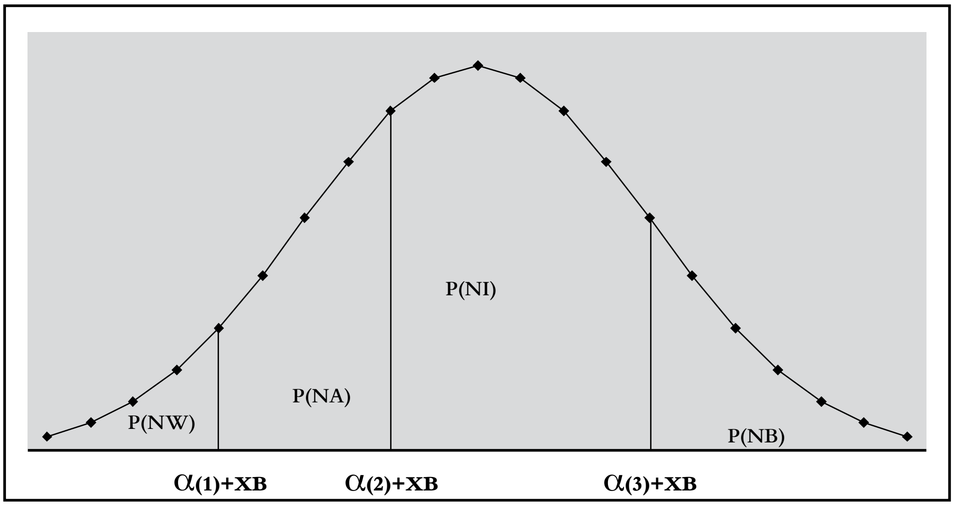
APPENDIX 1

THE ORDERED CATEGORICAL PROBIT MODEL

We wish to investigate the association of certain business characteristics, denoted by the vector **X**, with the highest degree of novelty of innovation. Thus we have as the dependent variable y = the ***highest*** degree of novelty of innovation, with values in the ordered set {NB < NI < NA < NW} where NB, NI, NA, NW represent 'new to the business', 'new to the industry', 'new to Australia', and 'new to the world' respectively. Each innovating business in the survey must identify one and only one of these highest degrees of novelty for its innovation.

Figure A 1.1 illustrates the model's allocation of probabilities across degrees of novelty. The left most vertical line lies above the value α (1) + **X.B**, where α(1) and **B** are determined in the estimation procedure; the next above α (2) + **X.B**, and the third above α (3) + **X.B**. The partition of the area under the normal density function defined by these vertical lines corresponds to the model estimates of the probability of the business achieving a highest degree of novelty of: new to the world, P(NW); new to Australia, P(NA); new to the industry P(NI); or new to the business P(NB).

Figure A 1.1: Illustration of model probability outcomes



As (most of) the conditioning variables in our case are discrete the 'marginal effects', and/or 'elasticities' typically implied directly by the estimated coefficients of continuous conditioning variables are not applicable here. Instead, for one or more conditioning variables of interest we need to decide on a discrete shock and apply that at a particular value of the conditioning vector **X**.

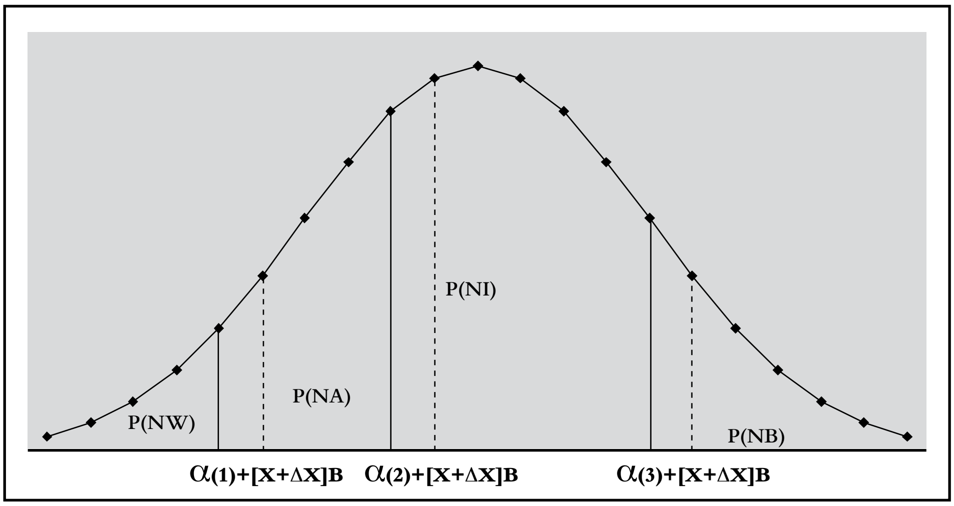
The particular value of **X** at which the shock is applied is discretionary but is frequently taken to be the mean value of **X** or the nearest discrete point to the mean value, denoted by $\overline{X}$. One or more of the components of **X** are then shocked by a discrete amount ΔX.
The impact of this shock on the various probabilities being modelled is then computed directly, for example

$$\Delta \mathbf{P(y = NW) = P(y = NW :} \overline{X} \mathbf{+ \Delta X\ ) - P(y = NW :} \overline{X}\mathbf{)}$$

and similarly for the other response probabilities. These responses can be expressed in absolute terms or as a percentage change to the probabilities evaluated at $\overline{X}$. Figure A 1.2 illustrates the impact of a discrete increase in a conditioning variable with a positive coefficient on the degree of novelty probabilities shown in Figure A 1.1. The vertical dashed lines lie above the values α (1) + [**X** + ΔX].B, α (2) + [X + ΔX].B, and α (3) + [X + ΔX].B from the left respectively – the solid lines are as in Figure A 1.1. The new (shocked) probabilities are depicted by the components of the partition defined by the dashed vertical lines.

Notice that as **X.B** increases P(NW) unambiguously increases, and P(NB) unambiguously decreases. However, in general, the sign of the change in the other probabilities is not unambiguously determined by the sign of the coefficient of the shocked variable. In the case illustrated P(NA) increases and P(NI) decreases.

Figure A 1.2: Impact on novelty probabilities of applying a shock to conditioning vector X



The fact that the response probabilities are dependent on the base value of $\mathbf{X}$ to which the shock is applied is often of very direct interest to the analyst. For example one of the conditioning variables in this paper is the industry to which the business belongs. It is of interest to compare across different industries the estimated impact of shocking a variable such as collaboration. The response probability resulting from a common collaboration shock is computed at each of the different values for the industry variable, and then compared across industries.

APPENDIX 2

IMPACT OF COLLABORATION – ADDITIONAL INDUSTRY TABLES

Table A 2.1: Impact of collaboration on the probability of achieving a specific highest degree of novelty, by firm size – *'Average' Mining**

Probability of Being	Collaborator			Non-Collaborator			Proportionate Increase in Probability (%)		
	L	M	S	L	M	S	L	M	S
New to World	18.7%	15.7%	12.9%	11.4%	9.2%	7.3%	64	71	77
New to Australia	25.8%	24.2%	22.2%	21.1%	19.0%	16.8%	22	27	32
New to Industry	21.4%	21.5%	21.5%	21.2%	20.7%	19.8%	1	4	9
New to Business	34.1%	38.6%	43.4%	46.3%	51.1%	56.1%	-26	-24	-23

* Increase in probability may not match proportionate changes in probability in table because of rounding. Percentage increase in probability is correct to nearest whole number.

Table A 2.2: Impact of collaboration on the probability of achieving a specific highest degree of novelty, by firm size – *'Average' Accommodation, cafes and restaurants, and cultural and recreational services**

Probability of Being	Collaborator			Non-Collaborator			Proportionate Increase in Probability (%)		
	L	M	S	L	M	S	L	M	S
New to World	12.9%	10.6%	8.5%	7.4%	5.8%	4.5%	74	83	89
New to Australia	22.3%	20.3%	18.2%	16.9%	14.8%	12.8%	32	37	42
New to Industry	21.5%	21.1%	20.3%	19.8%	18.7%	17.4%	9	13	17
New to Business	43.3%	48.0%	53.0%	55.9%	60.6%	65.3%	-23	-21	-19

* Increase in probability may not match proportionate changes in probability in table because of rounding. Percentage increase in probability is correct to nearest whole number.

Table A 2.3: Impact of collaboration on the probability of achieving a specific highest degree of novelty, by firm size – *'Average' Finance, property and business services**

Probability of Being	Collaborator			Non-Collaborator			Proportionate Increase in Probability (%)		
	L	M	S	L	M	S	L	M	S
New to World	13.3%	10.9%	8.7%	7.6%	6.1%	4.7%	75	79	85
New to Australia	22.6%	20.6%	18.5%	17.2%	15.2%	13.1%	31	36	41
New to Industry	21.5%	21.1%	20.5%	19.9%	18.9%	17.5%	8	12	17
New to Business	42.6%	47.3%	52.3%	55.2%	59.9%	64.7%	-23	-21	-19

* Increase in probability may not match proportionate changes in probability in table because of rounding. Percentage increase in probability is correct to nearest whole number.

Table A 2.4: Impact of collaboration on the probability of achieving a specific highest degree of novelty, by firm size – *'Average' Transport and communications**

Probability of Being	Collaborator			Non-Collaborator			Proportionate Increase in Probability (%)		
	L	M	S	L	M	S	L	M	S
New to World	13.6%	11.1%	9.0%	7.8%	6.2%	4.8%	74	79	88
New to Australia	22.8%	20.9%	18.7%	17.4%	15.3%	13.3%	31	37	41
New to Industry	21.5%	21.2%	20.5%	20.0%	19.0%	17.7%	8	12	16
New to Business	42.1%	46.8%	51.8%	54.8%	59.5%	64.2%	-23	-21	-19

* Increase in probability may not match proportionate changes in probability in table because of rounding. Percentage increase in probability is correct to nearest whole number.

Table A 2.5: Impact of collaboration on the probability of achieving a specific highest degree of novelty, by firm size – *'Average' Wholesale and retail trade**

Probability of Being	Collaborator			Non-Collaborator			Proportionate Increase in Probability (%)		
	L	M	S	L	M	S	L	M	S
New to World	16.6%	13.8%	11.3%	9.9%	8.0%	6.3%	68	73	79
New to Australia	24.8%	23.0%	20.9%	19.7%	17.6%	15.5%	26	31	35
New to Industry	21.6%	21.5%	21.2%	20.9%	20.1%	19.0%	3	7	12
New to Business	37.0%	41.7%	46.6%	49.5%	54.3%	59.2%	–25	–23	–21

* Increase in probability may not match proportionate changes in probability in table because of rounding. Percentage increase in probability is correct to nearest whole number.

APPENDIX 3

MANUFACTURING TECHNOLOGY CONCORDANCE

NACE Rev 1.1 CODE	NACE Description	ISIC Rev 3.1 CODE	ISIC Description	ANZSIC CODE	ANZSIC Description
High-technology manufacturing industries					
35.3	Aerospace	353	Manufacture of aircraft and spacecraft (353)	2824	Aircraft manufacturing
24.4	Pharmaceuticals	2423	Manufacture of pharmaceuticals, medicinal chemicals and botanical products (2423)	2543	Medicinal and Pharmaceutical Product manufacturing
30	Computers, office machinery	300	Manufacture of office, accounting and computing machinery (300)	2841	Computer and Business Machine Manufacturing n.e.c
32	Electronics-communications	321, 322, 333	Manufacture of electronic valves and tubes and other electronic components (321), television and radio transmitters and apparatus for line telephony and telegraphy (322), television and radio receivers, sound or video recording or reproducing apparatus and associated goods (323)	2849 2842	Electronic Equipment Manufacturing n.e.c (2849) Telecommunications, Broadcasting and Transceiving Equipment Manufacturing (2842)
33	Scientific Instruments	331, 332	Manufacture of Medical, Precision(331) and – Optical instruments (332), Watches and Clocks	283	283 – Photographic and optical good manufacturing (2831), Medical and Surgical Equipment(2832) manufacturing Professional and Scientific Equipment (2839).
Medium-High-technology manufacturing industries					
31	Electrical machinery	311-315, 319	Manufacture of electrical machinery and apparatus n.e.c (311-315) and other electrical equipment (319)	2852, 2853, 2854, 2859	Electrical Equipment manufacturing, – including electric cable and wire, battery manufacture, electric light and sign and other equipment (NACE 31 does not include domestic appliances – see NACE 29)

NACE Rev 1.1 CODE	NACE Description	ISIC Rev 3.1 CODE	ISIC Description	ANZSIC CODE	ANZSIC Description
34	Motor vehicles	341-342, 343	Manufacture of motor vehicles (341), manufacture of bodies for motor vehicles (coachwork) and trailers and semi-trailers (342), parts and accessories for motor vehicles and their engines (343)	281	281 - Motor vehicle manufacture (2811), including Motor Vehicle Body manufacture (2812), Automotive Electrical and Instrument manufacture (2813), Automotive Components manufacture (2819)
24 (excluding 24.4)	Chemicals -excluding pharmaceuticals	241-243	Manufacture of basic chemicals (241) and other chemical products (242), and man-made fibres (243)	253, 254, 2212	Basic Chemical manufacture (253), Other Chemical Product manufacture (254), Synthetic Fibre Textile manufacture (2212)
35.2, 35.4, 35.5	Other transport equipment	3520	Manufacture of railway and tramway locomotives and rolling stock (3520)	2823	Railway Equipment Manufacturing (2823)
29	Non-electrical machinery (and Domestic appliances)	291-293	Manufacture of general-purpose machinery and pumps compressors and valves (291), special-purpose machinery (292), domestic appliances n.e.c (293)	286, 2851	Industrial machinery and equipment manufacture (286) - including food processing and mining and construction equipment, and Domestic Appliance manufacture (2851)
Medium-Low-technology manufacturing industries					
23	Coke, refined petroleum products and nuclear fuel	231-233	Manufacture of coke oven products(231), refined petroleum products (232), processing of nuclear fuel (233)	251-252	Petroleum Refining (251), Petroleum and Coal Product manufacturing n.e.c.(252)
25	Rubber and plastic products	2511, 2519, 2520	Manufacture of rubber products (251) and plastic products (252)	255-256 except for 2564	Rubber product manufacture (255), Plastic Product manufacturing (256)
26	Non-metallic mineral products	2610, (2691-2696), 2699	Manufacture of glass and glass products (2610), Manufacture of non-metallic mineral products (2691-2696) and other non metallic mineral products n.e.c (2699)	26 except for 2610	26 - Glass and Glass Product manufacture, and other non-metallic mineral products, including concrete.
35.1	Shipbuilding	3511, 3512	Building and repairing of ships (3511), Building and repairing of pleasure and sporting boats (3512)	2821, 2822	Shipbuilding (2821) and Boatbuilding (2822)

NACE Rev 1.1 CODE	NACE Description	ISIC Rev 3.1 CODE	ISIC Description	ANZSIC CODE	ANZSIC Description
27	Basic metals	271, 272, 273	Manufacture of basic iron and steel (271), precious and non-ferrous metals (272), casting of metals (273)	271-273	Iron and Steel manufacture (271), Basic Non-Ferrous Metal manufacturing (272), Basic Non-Ferrous Metal Product manufacturing (273)
28	Fabricated metal products	281 (2811 -2813), 289 (2891-2893, 2899)	Manufacture of structural metal products, tanks, reservoirs and steam generators (281), manufacture of other fabricated metal products (289)	274-276, 2712, 2731, 2911	Structural Metal Product manufacturing (274), Sheet Metal Product manufacturing (275), Fabricated Metal Product manufacturing (276), Iron and steel cast forging (2712), Aluminium Rolling Drawing Extruding (2731), Prefabricated Metal Building manufacture (2911)
Low-technology manufacturing industries					
36, 37	Other manufacturing and recycling	361, 369 37	Manufacture of furniture and other manufacturing n.e.c., including jewellery	292, 294 2331, 2564, 2610	Furniture manufacturing (292), Other manufacturing (294) and Recycling in terms of - Aluminium Smelting (2723), Copper, Silver, Lead and Zinc Smelting, Refining (2723), Pulp, Paper and Paperboard Manufacturing (2331), Plastic Product Rigid Fibre Reinforced manufacturing (2564), Glass and Glass Product Manufacturing (2610)
20, 21, 22	Wood, pulp, paper products, printing and publishing	201-202, 210, 221-223	Wood, pulp, paper products, printing and publishing	23, 24 and 2229,	23 -Wood and Paper Product manufacturing (231-233), 24 - Printing Publishing and Recorded Media (241-243), Textile Product manufacturing (2229)
15, 16	Food beverage and tobacco	151-155	Manufacture of Food, beverages, tobacco products	21	21 - Food, Beverage and Tobacco

NACE Rev 1.1 CODE	NACE Description	ISIC Rev 3.1 CODE	ISIC Description	ANZSIC CODE	ANZSIC Description
17, 18, 19	Textile and clothing	171-173, 181-182, 191-192	Manufacture of Textiles, (171-173) clothing (181-182), tanning of leather, manufacture of handbags and footwear (191-192)	22	22 - Textile Fibre, Yarn and Woven Fabric manufacturing (221), Textile Product manufacturing (222), Knitting Mills (223), Clothing manufacture (224), Footwear manufacture (225), Leather and Leather Product Manufacturing (226)

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